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Research article

A sequential treatment of intermediate tropical landfill leachate using a sequencing batch reactor (SBR) and coagulation

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ABSTRACT

The increase in landfill leachate generation is due to the increase of municipal solid waste (MSW) as global development continues. Landfill leachate has constantly been the most challenging issue in MSW management as it contains high amount of organic and inorganic compounds that might cause pollution to water resources. Biologically treated landfill leachate often fails to fulfill the regulatory discharge standards. Thus, to prevent environmental pollution, many landfill leachate treatment plants involve multiple stages treatment process. The Papan Landfill in Perak, Malaysia currently has no proper leachate treatment system. In the current study, sequential treatment via sequencing batch reactor (SBR) followed by coagulation was used to treat chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N), total suspended solids (TSS), and colour from raw landfill leachate. SBR optimum aeration rate, L/min, optimal pH and dosage (g/L) of Alum for coagulation as a post-treatment were determined. The two-step sequential treatment by SBR followed by coagulation (Alum) achieved a removal efficiency of 84.89%, 94.25%, 91.82% and 85.81% for COD, NH_3-N, TSS and colour, respectively. Moreover, the two-stage treatment process achieved 95.0% 95.0%, 95.3%, 100.0%, 87.2%, 62.9%, 50.0%, 41.3%, 41.2, 34.8, and 22.9 removals of Cadmium, Lead, Copper, Selenium, Barium, Iron, Silver, Nickel, Zinc, Arsenic, and Manganese, respectively.

1. Introduction

With the aim of Malaysia to become an industrialized and sustainable country by the year 2020, it is inevitable that she faces some challenges regarding solid waste management like any other developing country. Landfilling remains the main disposal method of solid waste and there are 290 landfills in Malaysia in which 176 are still in operation and 114 were closed (Noor et al., 2013). In Malaysia, over 80% of the collected municipal solid waste (MSW) is landfilled and others are unsanitary, open dumpsite and overloaded in capacity (Fazeli et al., 2016). In Malaysia alone, 28,500 tonnes of MSW was generated daily (Agamuthu and Fauziah, 2011). According to Periathamby et al. (2009), over the past 10 years, the generation of municipal solid waste has increased more than 91% since the last 10 years due to change in consumption behavior, increase per capita income, migration of rural to urban and rapid development of urban areas like Kuala Lumpur and Ipoh.

The burial of MSW in Malaysia landfills cause landfill leachate to be generated when excess precipitation infiltrates through the many layers of the landfill. After the closure of the landfill, the landfill will continue to generate hazardous leachate which will be last for 30–50 years (Bashir et al., 2010). Landfill leachate contains mostly of organic matter both biodegradable and refractory to biodegradation (refractory compounds such as humic and fulvic acids) (Aziz et al., 2015; Shehzad et al., 2015), as well as heavy metals, ammonia-nitrogen, and chlorinated organic which if infiltrates and flows into nearby water bodies and into groundwater will poses adverse health effect to the surrounding soil and affecting the entire ecological system including human health (Renou et al., 2008; Azmi et al., 2016).

At present, Papan landfill in Perak does not have a proper leachate treatment system and the landfill is surrounded by streams and rivers. Hence, a proper treatment system is needed to

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treat the leachate before severely polluting the environment (Bashir et al., 2017). The classification of the landfill leachate age is important as a guideline to select which treatment is suitable for that particular leachate. Biological method (suspended or attached growth) is widely used worldwide for treating landfill leachate and considered the most environmental-friendly treatment with a cost-effective, simple and reliable treatment method to remove multiple contaminants like organic (BOD_5), inorganic and nitrogenous matter from young landfill where the BOD_5/COD ratio has a high value of more than 0.5 (Aziz et al., 2015; Bashir et al., 2015). SBR is the most applied technique in treating landfill leachate (Aziz et al., 2011) as SBR is ideal for completing the nitrogen cycle through nitrification-denitrification and can remove up to 75% of COD with excellent removal of ammonia-nitrogen, NH_4-N where the system has 20–40 days of residence time in treating domestic leachate (Renou et al., 2008). Furthermore, SBR treating leachate had achieved about 99% of NH_3-N removal efficiency as reported by Mace and Mata-Alvarez, (2002). Moreover, SBR has a smaller treatment plant footprint if compared to conventional activated sludge systems. According to Ismail et al. (2014), the process of aeration, mixing and sedimentation-clarification in the SBR are all performed in a single reactor, sequentially. Chang et al. (2000) mentioned that SBR can reduce the number of reactors as SBR consists of several time-oriented periodic steps and its batch operation can improve the process's efficiency comparable to plug flow reactor. Hence, using SBR will result in substantial reduction in capital cost for construction and operational cost (Chang et al., 2000).

Coagulation-flocculation is a common physicochemical process as pre or post treatment for many wastewater and landfill leachate which is coupled with biological treatment to improve the removal of bio-refractory and other non-biodegradable materials like humic and fulvic acids which are very hard to be removed in conventional SBR. Undesirable compounds in landfill leachate namely heavy metals, adsorbable organic halogens (AOXs), polychlorinated biphenyls (PCBs) and others were effectively being removed using this method. Coagulation-flocculation is more efficient in treating intermediate and stabilized or matured leachate (COD removal up to 75%) compared to young leachate COD removal up to 25–38%) (Wiszniowski et al., 2006).

The main aim of this research is to investigate the efficiency of sequential treatment (SBR/coagulation) of intermediate tropical landfill leachate. An intermediate leachate collected from Papan landfill was treated using SBR with different aeration rates (L/min) followed by coagulation using Alum. The sludge in the SBR was collected from palm oil mill wastewater treatment facility at Tian Siang oil mill (Air Kuning) in Perak. The treatment efficiency of SBR and coagulation process in treating leachate on chemical oxygen demand (COD), ammonia-nitrogen (NH_3-N), total suspended solids (TSS) and colour as well as the effect of the two-stage treatment system on heavy metals remediation are evaluated.

2. Materials and methods

2.1. Leachate and sludge samples collection

The leachate sample was collected from "Tapak Pelupusan Sisa Pepejal, Wilayah Ulu Johan Papan" (Papan Sanitary landfill) located at Papan District between towns of Papan and Lahat, Perak, Malaysia. Papan Sanitary Landfill is a level IV centralised high capacity sanitary landfill. Having a total area of 560.24 acres or 226.73 ha, Papan landfill has a capacity in receiving up to 800 tonnes of dumps per day from Districts of Ipoh, Batu Gajah, Kampar and Central Perak (Negeri Perak, 2013). Moreover, the lifespan of the landfill is projected to last for 35 years (Ipoh Echo, 2012).

The sludge sample from palm oil mill wastewater treatment facility was collected from Tian Siang Oil Mill (Air Kuning) Sdn. Bhd. which locates in the District of Batang Padang, Perak, Malaysia. The collected samples were then sent to the environmental laboratory and stored at 4 °C to minimize any biological or chemical reactions. Standard Methods for the Examination of Water and Wastewater and Hach Water Analysis Handbook were followed to determine the characteristics of the collected raw leachate at Papan landfill site (American Public Health Association (APHA, 2005; Hach, 2005). Heavy metals present in the leachate are analyzed by using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS, PERKIN ELMER NEXION™ 300Q, USA).

2.2. Setup of the laboratory-scale SBR

In this research, there were six SBRs each individually made up of a 1.5 L mineral plastic bottle bio-reactors made from polypropylene (PET) in which being held firmly by clamp attached to a retort stand. To provide proper mixing and sufficient dissolved oxygen (DO) in the reactor, each SBR employed a set of pump with a flow meter connected between the pump and the reactor to control the air-flow rate as well as to provide constant aeration and mixing during the reacting period. The reactors were divided into three groups with each comprising of two SBR with flow-rate of 1 L/min, 3 L/min and 5 L/min, respectively. The concentration of COD, NH_3-N, TSS and colour were tested according to HACH Method 8000 (Dichromate Reactor Digestion Method), Spectrophotometric Method-Single Wavelength Method and HACH Method 8006, respectively. The removal efficiency was calculated by using Eq. (1):

$$\text{Removal efficiency, } \% = \left(\frac{C_i - C_f}{C_i}\right) \times 100\% \quad (1)$$

where C_i and C_f refer to initial and final concentration of COD, NH_3-N, TSS and colour.

Fig. 1 shows the schematic diagram of SBR set-up.

2.3. Experimental run – SBR

The experiment run was conducted to study the cultivation and acclimatization process of aerobic microbes in the SBR. The cultivation was done during 10 days. Each reactor (1.5 L) was filled with 80 ml of leachate and 720 ml of fresh palm oil mill sludge with a mixing ratio of 1:10. During the sludge cultivation period, the sequential operation of the reactor comprises filling and mixing (20 min), react and aeration (22 h), settling (90 min) and drawing (10 min) which the complete cycle of the SBR. Supplementary material 1 illustrates the sequential stage of a complete 24 h cycle of SBR.

During the cultivation period, the hydraulic retention time (HRT) and sludge retention time (SRT) of the SBR were fixed at 10 days and 30 days, respectively. The SBRs was operating at room temperature condition (23 °C–26 °C). The air was supplied by an aquarium air pump (Network, Japan NS aquarium air pump, Model: L-15, Power: 8 Watts, Maximum air flow-rate: 12 L/min). The air flow rate was controlled by an air flow meter (SHLLJ ACRYLC Flow meter, Model: LZM-6, Range: 0–10 L/min).

2.4. Post treatment process

The purpose of post treatment is to further treat the effluent from the SBR to meet discharged standard. Aluminium Sulphate (Alum) with chemical formula: $Al_2(SO_4)_3 \cdot 16H_2O$ and molecular weight of 630.39 g/mole was used as a coagulant for post treatment after SBR. Effluent samples from SBR were transferred into 50 mL